

# Detection of Explosives With the M4A1-JCAD Without Hardware Modifications – The Chemical Explosives Detector

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## Chemical Warfare Agent Detectors for Explosives – M4A1-JCAD

The utility of using the fielded M4A1-Joint Chemical Agent Detector (JCAD) chemical warfare agent (CWA) detector for detection of explosives, without modification of the M4A1-JCAD hardware, has been demonstrated.

Prototype add-on explosives sampling and sample introduction systems have been produced and laboratory feasibility experiments have been performed. Explosives detection databases have been acquired and are being expanded along with detection algorithms. The premise of this project is to develop an explosives detection capability with existing CWA detection equipment, without having to resort to hardware modification of the existing detectors, and without compromise of the CWA detection functions. The M4A1-JCAD is based on Ion Mobility Spectrometry (IMS) technology, as are all automatic point sampling CWA detectors in the U.S. military (M4-JCAD, M4A1-JCAD, M22-ACADA and I-CAM); therefore, the databases generated for this project are applicable to the other CWA detection systems.

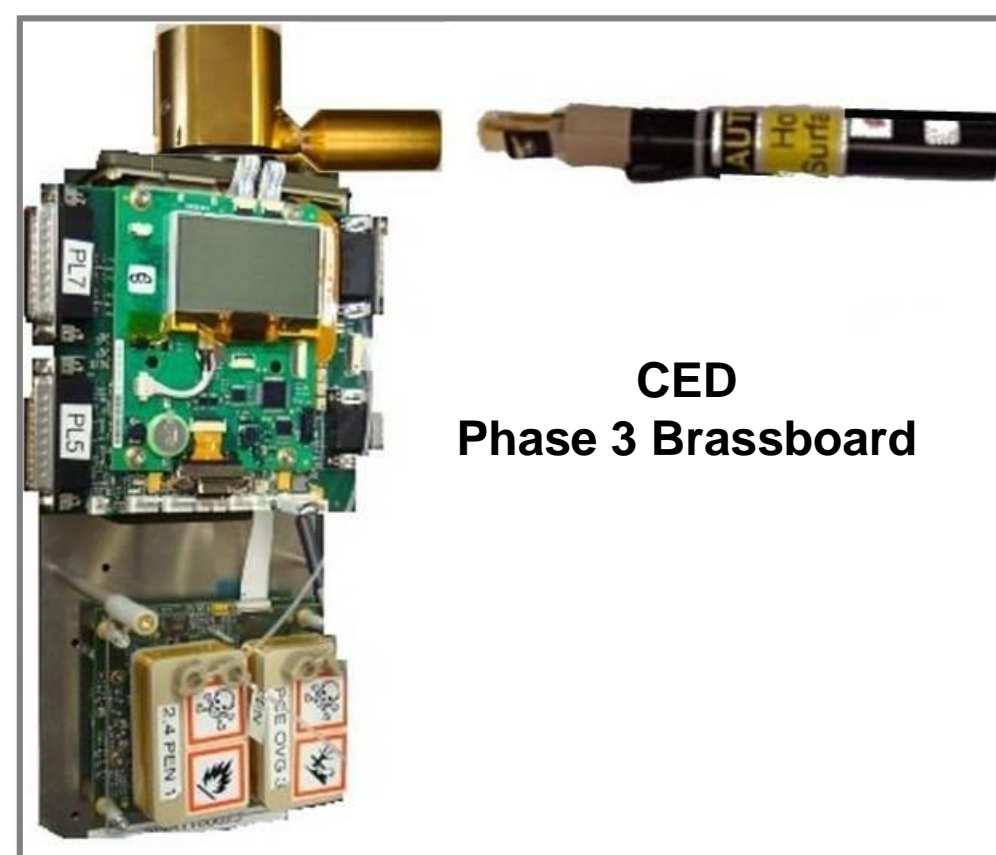
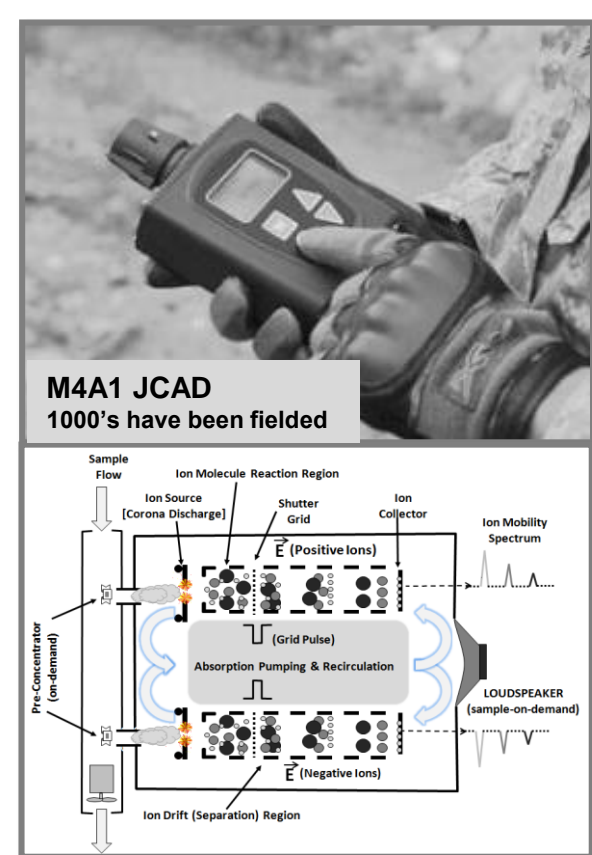
M4A1-JCAD response data has been generated for explosives and related materials, including di-nitrotoluene (DNT), tri-nitrotoluene (TNT), pentaerythritol-tetranitrate (PETN), ethylene-glycol-dinitrate (EGDN), ammonium-nitrate (AN), calcium-ammonium nitrate (CAN), dimethyl-dinitrobutane (DMNB), cyclo-trimethylene-trinitramine (RDX and C-4), 2,4,6-trinitrophenylmethyl nitramine (Tetryl), ammonium and potassium perchlorates. Limits of detection (LoD) as low as 10 ppbm (part-per-billion mass ratio) have been demonstrated; signal-to-noise ratios indicate that an order of magnitude reduction in LoD is possible without hardware modifications. Limits of detection are orthogonally validated using gas chromatograph-mass spectroscopy analytical techniques.

External hardware attachments include a sampling probe swab for collecting explosives samples from surfaces, a modified JCAD rain cap (external add-on item) for accepting the sampling probe and transferring explosives vapor samples from the probe swab to the detector, an “on-demand” vapor generator for real-time introduction of an ion mass spectrometer calibrant and a chemical dopants to enhance system responses to some of the explosives. Operational software for the probe swab, vapor generators, and data acquisition has been developed. Optimization of sampling and analysis methodology is continuing.

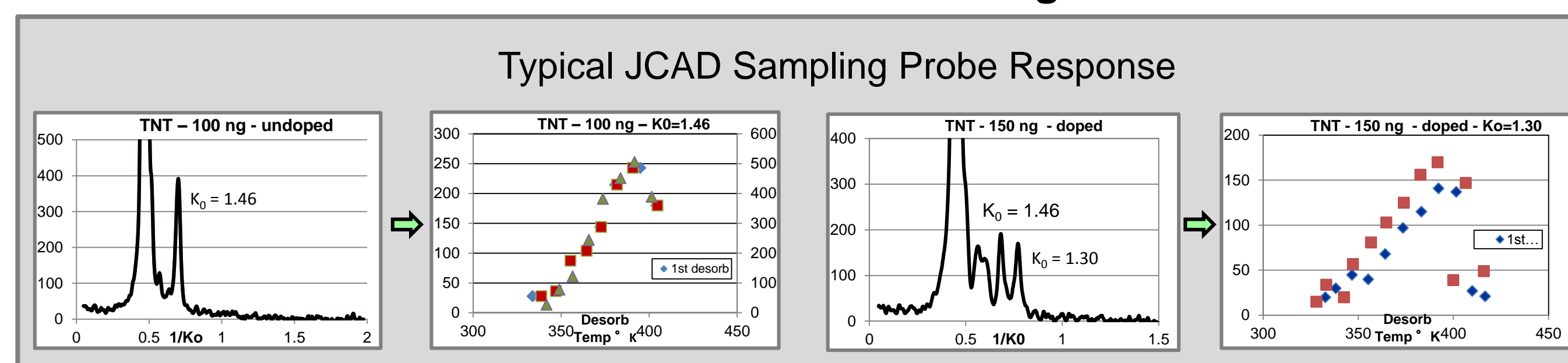
In order to provide explosives detection capabilities using CWA detectors, with only software modifications, false alarms are addressed. To this end, accurate and precise ion mobility values are being obtained for target compounds vs. temperature, electric field strength, atmospheric pressure, and drift gas water concentration in positive and negative ionization modes; the goal is accuracy of measurements an order of magnitude better than literature values. Parametric measurements are made using commercial NIST-traceable sensors. Ion mobility values are determined using a hybrid IMS-time-of-flight mass spectrometer for high resolution product ion identification. Accurate, precise ion mobility constants result in narrowing detection spectrum windows to reduce potential for false alarms without affecting detection sensitivity.

This project demonstrates detection of explosives and precursor materials in existing CWA point detection systems and demonstrates feasibility for integration of explosives detection into the family of chemical, biological, radioactive and nuclear (CBRN) point detectors. The work will integrate hazard detection equipment and reduce the overall number of types of detection equipment fielded; saving purchase and maintenance cost, as well as training time.

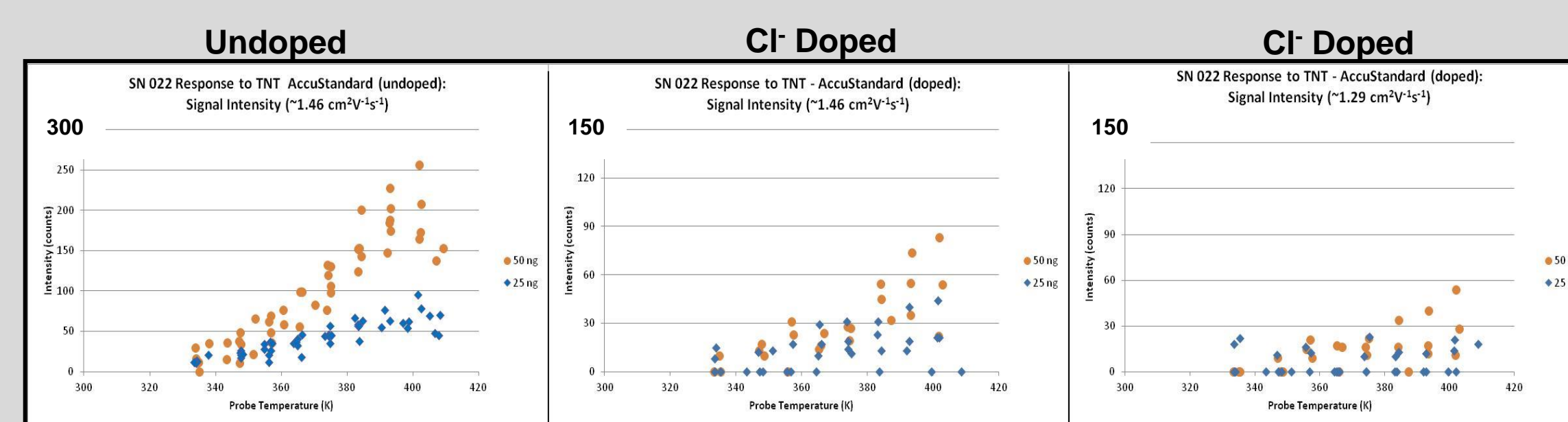
## M4A1-JCAD to Chemical Explosives Detector



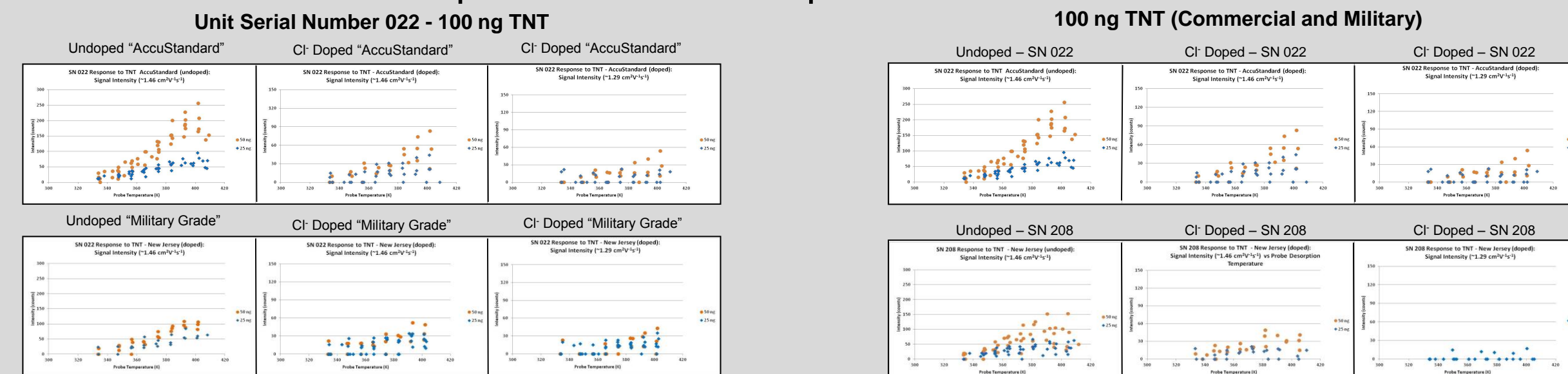
## CED Particulate Testing



## Compare Doped Detector vs Undoped - 100 ng TNT

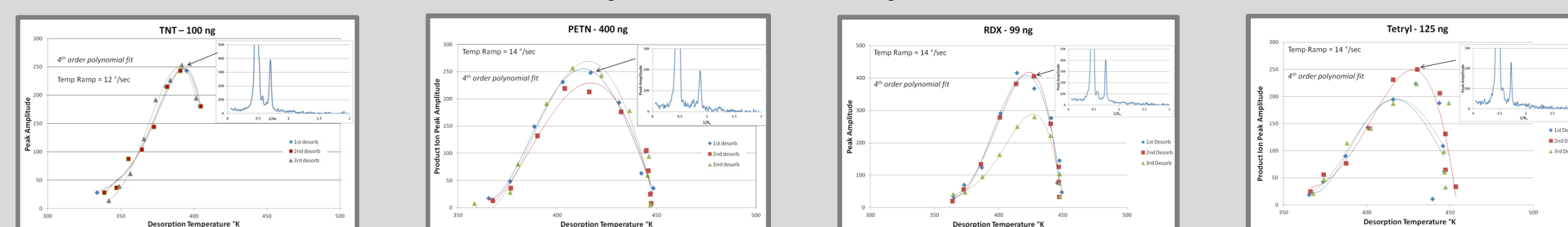


## Compare Sources of Explosives and Detectors

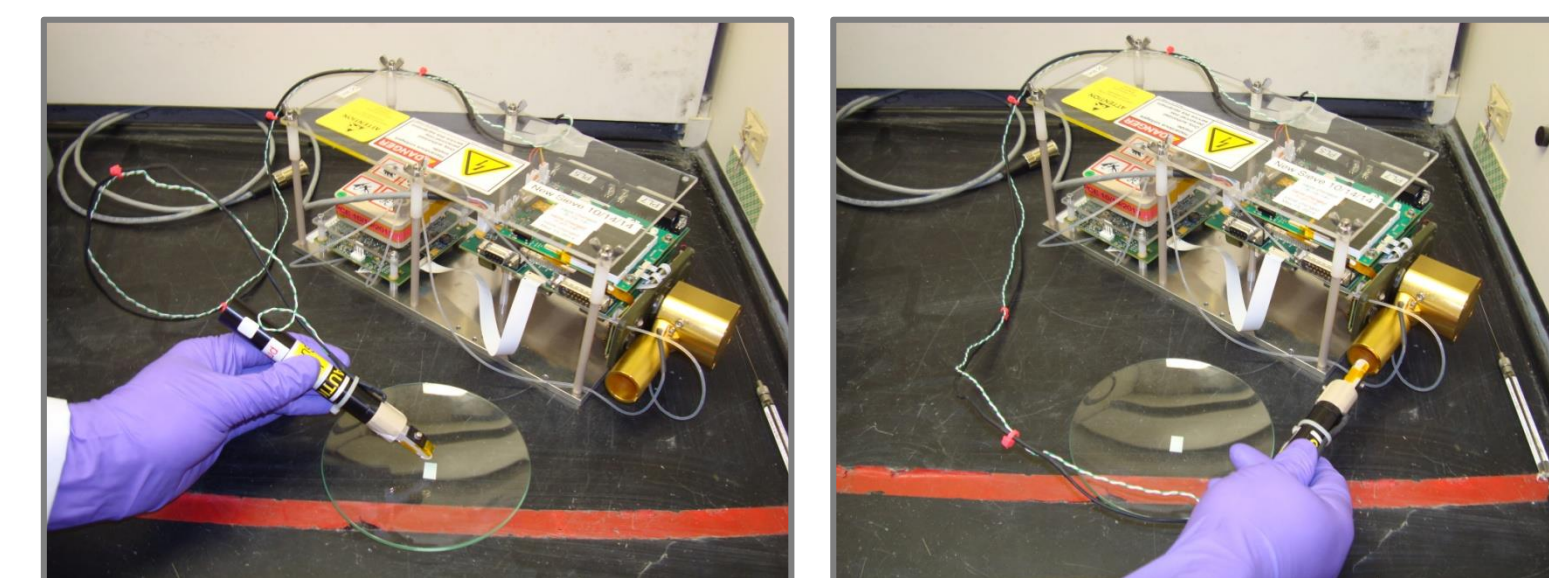


## Low Volatility Explosives Detection

### Triplicate Swab Desorption



## Experimental Methods

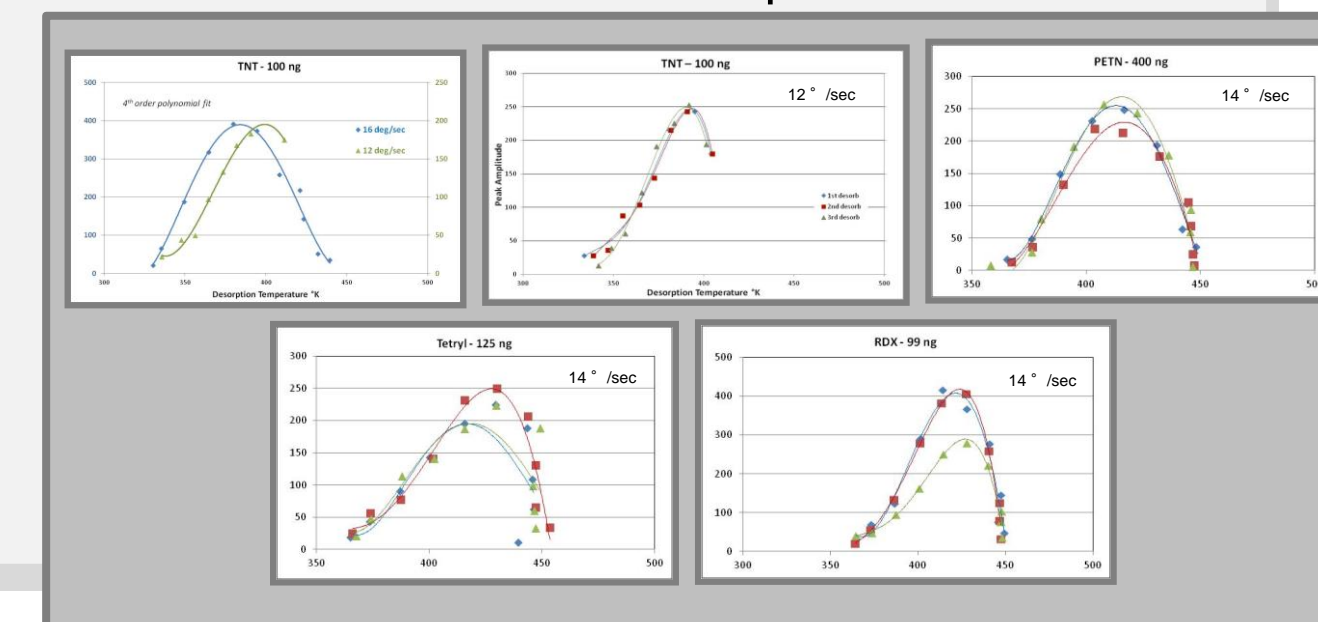


- JCAD with external, add-on modifications
  - Design and fabricate sample inlet, rain cap, replacement
  - External source of temperature control
  - External power
  - External dopant source
  - Leverage approaches in commercial detectors, i.e., swab sampling
  - JCAD maintained at ambient temperature

- Explosives deposited on glass substrate
  - Dilutions of “AccuStandards” and military explosives
  - Quantitative solutions – CH<sub>3</sub>CN and MeOH solvents
    - 1 – 2 µL
    - Evaporate solvent
  - Sample transfer via proprietary swab

## Desorption Profiles

6-7 sec desorption



## Conclusions

- Existing M4A1-JCAD can provide explosives detection capabilities for non-volatile and semi-volatile explosives
  - TNT, RDX, PETN, EGDN, DMNB, 2,4-DNT demonstrated
  - Limits of Detection < 10 ppbv
- Add-On JCAD peripherals are promising and are being evaluated
  - Hardware is at breadboard stage – brass boards under construction (*Deliverable April 2015*)
  - Databases are being populated for software and algorithm development
  - Limits of Detection at about 10 nanogram level
- Accurate ion mobility constants and water vapor compensation for enhanced detection and discrimination algorithms have been obtained.
- Response characteristics, e.g., thermal desorption profiles, appear to be useful for improved detection of low volatility explosives and CWA.
- CWA detection capabilities for M4A1-JCAD are maintained.

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